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ABSTRACT

This report describes a study which examined the ways in which children interact and make sense of a range of mathematics problems by working in pairs. Studies of collaborative peer dyads' problem solving have generally been influenced by Piagetian or Vygotskian theories and research approaches. It is noted that the process of dyad collaboration and its supposed benefits requires further examination with children on a range of problems to more precisely understand how dyads may construct meaning and how the collaborative process may influence this. This study had the following three purposes: (1) to provide novel and fresh slants on collaborative peer dyad; (2) to understand what lies behind children's problem redefinition in collaborative peer dyads; and (3) to provide intricate details of the phenomenon of collaboration, problem redefinition and the effects of the problem type on these. The subjects in this study were eight children from two elementary schools in Waikato region of New Zealand. The results indicated that collaboration increased for all dyads over time, and some problems appeared to engender more collaboration than others. The paper concludes with a series of questions raised by this study and provides suggestions for further studies. Contains 37 references. (MOK)

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Abstract

The studies that have been undertaken on collaborative peer dyads' problem solving have generally been influenced by Piagetian or Vygotskian theories and research approaches. As such these studies have contributed a wealth of information on dyads performance with problems, especially when compared with individuals. Research in the neo-Vygotskian tradition has attempted to explore the processes that dyads use when undertaking problem solving. The process of dyad collaboration and its supposed benefits requires further examination with children on a range of problems to more precisely understand how dyads may construct meaning and how the collaborative process may influence this.

Introduction

The majority of studies on collaborative peer dyads originated in cognitive research with experimental studies undertaken in laboratory or school settings. The classical approach in such studies is the use of Piagetian tasks and positivist pre-test, post-test designs. Studies in this ilk compared the performance of individuals with collaborative dyads and emphasised the crucial role of conflict in creating cognitive dissonance and subsequent development. More recent collaborative peer dyad research (particularly that from a neo-Vygotskian perspective) has surmised that children's complementary roles in dyads and their co-construction of meaning forms the basis of dyad effectiveness in problem solving. The theoretical framework evolving in this qualitative study acknowledges the influence of the Piagetian and Vygotskian tradition but does not reflect the either/or perspective of these theories. Instead it attempts to make explicit the conditions under which children collaborate, hold contrasting views, and develop complementary roles, amongst other actions and interactions. The central phenomenon of 'collaborative sense-making' is emerging continuously in the data and forms the pivot point of this study. This paper reports on a study which is currently ongoing. As such the findings reported here are tentative and preliminary.

Initial Research Questions

After a review of the literature and a number of classroom observations, the following research questions have emerged and provide some direction for this study. This year-long study of collaborative peer dyads (children working in pairs) focuses on the ways in which children interact and make sense of a range of problems in mathematics. These questions act as signposts for the structure of the methodology and subsequent analysis. As is typical of interpretive research though (and particularly of grounded theory) these questions contribute starting points for the 'journey', rather than precisely map the terrain that will be covered.

1. What characterises a collaborative peer dyad (cpd)? What is educative about a cpd?

While various claims have been made about the nature and effectiveness of peer dyads little is known about the factors that contribute to the efficacy of collaborative dyads. While some researchers argue for the central role of conflict in collaborative peer dyads (e.g. Doise & Mugny, 1984; Howe, Tolmie & Anderson, 1992; Light & Glachan, 1985; Perret-Clermont, 1980; Piaget, 1950) there is some evidence that other factors such as support, problem clarification and the construction of meaning may be more significant (e.g. Barnes & Todd, 1977; Forman, 1981; Forman & Cazden, 1985; Garton & Renshaw, 1988; Light, Foot, Colbourn & McClelland, 1988; Light, Littleton, Messer & Joiner, 1994; Mercer, 1994, 1995). An interpretive approach to this question seeks to understand the ways in which children in their interactions, mutually influence each other's thinking.

2. *How do cpds construct and make sense of problems?*

Many peer interaction studies have focused upon cognitive gains which have been 'measured' with positivist pre-test, post-test designs. The focus of such research reflected Piagetian theories on cognitive development. Indeed, many of the studies on cpds were experimental designs using Piagetian tasks within laboratory or school settings. The performance of individuals was compared with cpds on the same tasks (e.g. Doise & Mugny, 1984; Tudge, 1990), and depending upon the composition of the dyad, cpds were found to generally perform better than those children who worked alone. Vygotskian theory is frequently contrasted with Piagetian theory with Piaget (1950) focusing on the cognitive development of individuals and Vygotsky (1978) focusing on social-cultural factors in learning. Piaget did make numerous references to collaboration between children, particularly with his theory of socio-cognitive conflict, but factors such as culture and peer communication featured little in his empirical research. Vygotsky however, focused closely upon "talk as a medium for sharing knowledge and potentially, transforming understanding" (Mercer, 1994, p. 95). The neo-Vygotskian perspective (variously called 'socio-cultural-developmental theory' or 'cultural psychology'; Mercer, 1994) emphasises the *process* of communication and language instead of a primary focus on the *product* or outcome of collaboration. As such, research in this ilk has emphasised the ways in which children socially interact and communicate *during* activities and discussion. As this study seeks to investigate the meanings children construct together, the neo-Vygotskian perspective has an influence on the methodology. The experimental paradigm of Piagetian and neo-Piagetian research resulted in laboratory methods and detached, 'objective' researcher roles. In contrast, Vygotsky's work has encouraged a shift towards more naturalistic methodologies and "the investigation of cognitive development and learning in context" (Mercer, 1994, p. 95).

3. *What sense is made of different types of problems? What problem redefinition occurs in cpds?*

Whilst responses to different problem types has been investigated by Maker (1993), she focused on individuals (not dyads) using a structured experimental approach outside the classroom and compared gifted and 'average' populations. This study also seeks to understand the ways in which children affect each other's thinking when engaged with a range of types of problems. A focus upon problem redefinition may further illuminate the processes involved in children's problem solving and posing. Understanding more about problem redefinition and the part that cpds play in this, may raise significant pedagogical issues.

Research Design

As this study endeavours to examine both collaborative peer dyads and problem redefining in these dyads, substantially qualitative approaches are required. This interpretive study is concerned with the content and nature of the meaning-perspectives of children in dyads as intrinsic to their collaborative work. The purpose of the classroom field work is not to 'answer' "Which types of problems are most effective in enhancing peer collaboration?" or "How does problem redefinition occur in collaborative dyads?" but rather to subject to critical scrutiny assumptions about the meanings children hold about different problems and assumptions about problem redefinition in collaborative peer dyads (Erickson, 1986). In this study I am also seeking to understand the ways in which children in their interactions, mutually influence their thinking and their environment. Strauss and Corbin (1990) attest that the purpose of interpretive research is:

> To uncover and understand what lies behind any phenomenon about which little is yet known. It can be used to gain novel and fresh slants on things about which quite a bit is already known. Also qualitative methods can give the intricate details of phenomena that are difficult to convey with quantitative methods. (p.19)

In keeping with the spirit of interpretive enquiry this study aims to:

- provide novel and fresh slants on cpds
- understand what lies behind children's problem redefinition in cpds (about which little is known)
- provide intricate details of the phenomenon of collaboration, problem redefinition and the effects of the problem type on these.

Thus the aim is not to prove causality between effective problem solving and cpds, or problem redefinition and cpds, but rather to convey plausibility (Erickson, 1986). Interpretive approaches are appropriate for this study as the setting is holistic and greater attention can be given to nuance, idiosyncrasies, serendipity, interdependencies and complexities (Patton, 1990).

While grounded theory (Strauss & Corbin, 1990) forms the basis of the coding, categorisation and analysis, the other theories have some relevance for this study. These theories include Vygotskian theory and neo-Vygotskian research (e.g. McLeod, 1995) and Information processing theory and research (e.g. Sternberg, 1988). The literature in these areas do not comprise the theoretical framework of this study but cognisance of these theories is an acknowledgment of the pertinence of these contributions.

Method

The methodology has evolved alongside the theoretical framework of this interpretive study. The pilot phase of the methodology was a design where there was control over the type of problems provided, the choice of problems and the order of problems presented to dyads. While this phase of the research was undertaken in the children's own classroom and they were already familiar with the researcher, there remained elements of the procedure that were highly structured. It could be argued that such a methodology varies little from the more clinical dyad studies undertaken in laboratory settings using Piagetian tasks and positivist pre-test, post-test designs. However some significant differences merit mention. Most previous studies have focused on cognitive gains on a particular task and compared dyads with children working alone. This methodology incorporates a range of problems from closed (those that have one right answer) through to ill-defined (those that require defining and may have a number of possible answers).

Problem types:

The tool used for determining the types of problems employed is influenced by Getzels and Csikszentmihalyi (1967); Maker (1993) and Schiever (1991). That children could well *redefine* problems that are presented to them is also of interest and has significance for this study. Three problem types were employed:

Type 1

Closed problem (C). The problem is clearly defined and known to both presenter and solver. The method(s) for solving are not stipulated, and there is one correct answer which

is known to the presenter. An example of this would be when children are asked "The doctor says to take 5 pills, one every half hour. How long will that take?"

Type 2

More than one solution and strategy possible (M). The problem is known to both presenter and solver but a range of methods for solving is possible, as is a range of solutions. An example would be when the problem states "Jill saw some friends with tricycles and bicycles. She saw 18 wheels. How many tricycles and bicycles might there be?"

Type 3

Fuzzy problem (F). While the problem may be known to both presenter and solver, it is ill-defined and many methods may exist for solving the problem or a new method may need to be devised. An example of such a problem would be when children are asked to "Estimate the number of vets in New Zealand". (These are also called 'Fermi' problems, based upon the types of problems that the physicist Enrico Fermi liked to pose which encouraged estimation and problem processing.)

The children were given 3 sets of 3 problems to work with over approximately 3 one hour sessions. The order of the problems varied each time so that they were not going from 'closed' to 'fuzzy' in each session but investigated the problems in different orders during each hour. The dyads were observed closely as they worked on the problems and interacted with each other. Audio and video-tape were used to capture interaction alongside continuous narrative recording. The technology for recording was introduced gradually over time to minimise any distraction. An open-ended interview was undertaken after each set of problems with each dyad to more precisely validate possible meanings that the children had developed during their interaction. The interviews assisted with clarifying the children's meaning-perspectives corroborating (or otherwise) what was observed and providing further illumination.

The second phase of the research was undertaken with a different group of 7 and 8 year old children selected for extension in mathematics. These children were withdrawn on a weekly basis from their classroom to work with peers of similar ability. Their programme consisted of a range of problem investigations including the types of problems aforementioned. Video-taping and audio-taping of conversations commenced with these dyads after a period of familiarisation with each other and the researcher and the development of a 'class culture'. The data gathered from this phase is deemed to be more 'naturalistic' in that many of the problems were similar to the ongoing investigations in the class programme.

Data source

The children in this study are from two elementary schools in the Waikato region of New Zealand. The school in the pilot phase is predominantly white and middle class. The school in the subsequent study is multicultural with children from low socio-economic backgrounds. As such, the majority of parents and caregivers are beneficiaries (56%) or in unskilled labour (36%). The majority of children have had no formal early childhood education. The composition of the school roll includes a number of different ethnic groups comprising Maori (Indigenous New Zealanders: 62%), Pakeha (White New Zealanders: 22%), Pacific Island (11%), Lao and others (5%). The 8 children in the main study are from 3 different classrooms within the school and range in age from 7.0 years to 8.6 years. The children chose their own partners for the dyad study with the exception of one dyad

who generally preferred to work separately (two boys from the same class). The dyads were matched for gender except for one boy-girl dyad.

The children were selected through a variety of procedures including anecdotal records, observation, parent, peer, self and teacher nomination as well as reference to standardised test scores where relevant. The criteria for selection was interest and ability in mathematics. Research indicates that when children are asked to work with a partner they are often working in parallel, rather than together (Kutnick & Rogers, 1994). Furthermore, when a dyad is asymmetrical (i.e. when one child is more advanced than the other) the more able child tends to dominate and instruct, rather than work collaboratively with their peer (Doise & Mugny, 1984; Kutnick & Rogers, 1994, Tudge, 1990). Therefore the dyads were chosen for commensurate or symmetrical ability to maximise the possibility that they may work together as partners and to diminish any peer tutoring effects. It was proposed at the outset that the extent to which they collaborate may reveal itself during the study i.e. the nature of the problems posed and the practice of working together may contribute to their collaboration.

Only one dyad from one class (the two boys) had been explicitly instructed by their classroom teacher as to how to work in pairs. This instruction included reminding the children that neither is the 'boss', to give eye contact to the other child, to listen, to agree to disagree at times, and decide upon who would report back. The classroom teacher concerned reported that these skills took considerable practice and that the children seemed to resist pair work initially. Although it is not the intent of this study to investigate ways in which children can be assisted to work collaboratively (and an extensive body of literature does exist on this) it is worth noting that children are often expected to work together without having the necessary skills and guidance in doing so.

The children were withdrawn from their classrooms once a week over a period of four months for mathematics enrichment and extension with a number of other children.

Interviews vs Conversations

The literature on interviewing children, particularly from Piaget and more contemporary developments in science education (Cosgrove & Osborne, 1981; Osborne & Cosgrove, 1983; Osborne & Freyberg, 1985) have focused upon set questions followed by further probing of the children's responses to those questions to clarify their meaning and ideas. In a sincere attempt to find out what children really thought (rather than what they thought adults wished them to disclose) these approaches did convey to children that their ideas were of interest and concern. What was not clear though was whether such interviews probed what children knew or what they were starting to know i.e. whether such interviews tend to focus on the ideas children hold rather than the ideas they are still formulating (Schaverien & Cosgrove, 1993). It may be that interviews of this nature do not reveal all that a child knows (about a certain subject) and certainly not all that they are beginning to know. As the open-ended interview employed during the pilot was undertaken at the end of each session, it was positioned as a formal reflection on what had taken place, rather than as a conversation. Conversations rarely only take place at the end of a series of activities but are more likely to occur between and during activities, such as the conversations partners have when changing sides in a tennis game. As this study intends to investigate the ways in which children affect each other's thinking it seems more relevant to employ a methodology that sheds some light upon the process of interaction as close to the action as possible. In doing so the conversations that take place may enable children to talk about their emerging understandings and thoughts rather than just responses to interview questions. The intention is to uncover the children's interaction and thoughts in process, including ill-formed and emerging thoughts.

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Coding and Analysis

Forming Sub-Categories

I have not used labelling of phenomena established by other researchers but rather have inductively devised my own from the acts in the data. The reliability of these sub-categories was tested in the earlier pilot phase and found to have 78.8% reliability with an untrained rater. It was predicted that reliability would be further strengthened when raters were trained. Validity of the labels was tested in discussion with two colleagues and with numerous rewordings, selection of relevant examples, recourse to dictionaries and thesaurus, clarifications, changes and amendments. Subsequent transcribing and coding using the labels derived from the above process was undertaken. This helped to clarify the sub-categories which emerged from the data. From this procedure emerged a list of 11 sub-categories (see Appendix 1) which formed the basis of the coding. Some sub-categories were formed by combining two concept labels which were complementary and in which there was a considerable degree of overlap e.g. 'counter' and 'correct' were initially recorded separately but the incidence and context of these phenomena resulted in a decision to form a sub-category consisting of both.

Issues in Developing the Sub-Categories

Individual or Social?

It could be readily argued that two sets of concept labels could have been derived for coding: one set based upon speech directed at oneself and one set classified as intended for another person (in this case, the dyad partner). However, such a form of coding separates individual acts from social acts in a fashion which makes an unhelpful distinction. The socio-cultural context is the focus of this study. This acknowledges the ways in which meaning can be jointly constructed between people and their interaction with their environment. Making discrete categories of individual and social utterances is problematic within such a study. Not only does it fragment the way in which social dialogue is constructed but it can obfuscate the way in which seemingly private utterances can influence another person present. Furthermore, studies on problem solving have found that the presence of a peer can effect what an individual does and says, even when they do not interact with their peer (Joiner, Messer, Light & Littleton, 1995).

Contemporary studies in collaborative problem solving have moved away from experimental designs focused on learning outcomes, to more in-depth study of children's dialogue when collaborating (Hoyles & Forman, 1995). Most of these studies have built their analyses on the coding of speech acts and interaction. However, Crook (1995) warns that coding speech can resort to the "static tabulations of its constituent utterances" (p. 544) which contributes little to the study of collaborative dialogue in process. In effect, the sub-categories listed above are both social and individual rather than reflecting some either/or distinction. They are uttered by individuals interacting with or in, the presence of a peer. They represent both 'talk within' and 'talk between', although some utterances may be considered more interactive than personal in purpose. In general though, the sub-categories have been constructed from the social context in which the talk was generated. Each label makes sense in terms of the context in which it occurred as an attempt to study the development of collaboration.

Properties and Dimensions

According to Strauss and Corbin (1990), properties make up a category and these can be dimensionalised across a continuum. This process forms the basis for making relationships between categories and subcategories. Properties and their dimensional range were explored in generating the above sub-categories which was a useful process in considering the range of plausible and possible responses which fitted within each sub-category e.g.

Subcategory	*Properties*	*Dimensional Range*
Hypothesise	Certainty	definite---------tentative
	Speculation	safe----------ambitious
	Specificity	clear----------vague

This consideration of the nuances and possible range of hypothesising assisted the classifying of the data into meaningful, rich subcategories which incorporated a range of possible forms. This has the benefit of being flexible and inclusive of the many types of statements that may be construed as 'hypothesising' rather than predetermining a narrow and restrictive definition. The limitation in this approach is that properties and their dimensional ranges are somewhat subjective as what seems 'tentative' for one person may appear 'definite' to another. This can especially be the case in cross-cultural communication which has been well documented in the literature (e.g. Metge & Kinloch, 1987).

Analysis

Further to generating properties and dimensions, other techniques from grounded theory procedure are incorporated to increase theoretical sensitivity and aid analysis. These include the 'flip-flop' technique (turning a concept upside-down to imagine its opposite), questioning, systematic comparison of two or more phenomena and axial coding. Strauss & Corbin (1990) state that axial coding is "a set of procedures whereby data are put back together in new ways after open coding by making connections between categories" (p. 96). Axial coding is particularly useful for understanding the phenomenon of problem redefinition. Subsequent selective coding from identification of the story line suggests at this stage, that the central phenomenon is collaborative sense-making. This phenomenon is evident over and over in the data as forms of intelligence gathering, explaining, proposing and clarifying. The specific sub-categories relating to this core category are seek information/verification, inform/verify, deduce and hypothesise.

Results and discussion

Results thus far indicate that collaboration increased for all dyads over time. By the third set of problems all dyads exhibited greater collaboration with each other and the task at hand. Furthermore, some problems appeared to engender more collaboration than others. There was less collaboration overall on the closed problems than any other problems. The dyad arrangement proved a useful site for social discourse with each child communicating their thinking at times through talking aloud to their peer. This occurred more frequently when the problems were open-ended or ill-defined. The ill-defined problems were pursued and enjoyed more by the confident and able children but again this developed over time. The dyads' favourite problem appeared to be that which engaged both their minds and their emotions. Some children reported a preference for problems which appeared relevant to their lived experience, such as going to a fair. However, some problems without any 'real' context (such as 'Make 23') were popular with all dyads nonetheless. The children

exhibited and reported excitement, relief and challenge during and after problems they enjoyed. Hearing their partner discuss ideas seemed to aid the problem solving process, even when those ideas were not agreed to. What appeared to be significant with the open-ended and fuzzy problems is that the children need each other in their attempts to unravel and construct meaning. With the closed problems there was less evidence of collaboration, less reciprocity of ideas, more likelihood of premature closure, less conflict and greater likelihood of the children misinterpreting what the problem meant.

The central phenomenon of collaborative sense-making emerged from the categorisation of the data. As collaboration developed in the dyads it appeared to aid problem solving and redefining, especially when the problem was open-ended or ill-defined and especially when the confidence of one child overcame the doubt of another. (Although the children were matched for ability, competence did not always match confidence and there was invariably one child who exhibited greater confidence than the other.) This confidence did not necessarily emerge as dominance but rather as persistence and refusal to concede a problem was impossible to solve.

Problem Redefinition

From axial coding it emerged that a common antecedent for problem redefinition was difference of opinion between the children and/or the need for clarification. The consequences of redefinition included refinement of concepts, further information seeking and often, progress with a new shared strategy. Problem redefinitions were not always automatically accepted by a peer who often sought explanation and corroborating evidence for the change in direction.

Conflict appears to be a significant causal condition for problem redefinition and this is more likely to occur when the problem is open-ended or ill-defined. This conflict appears to accrue benefits for both children when the opposing point of view is explained and clarified. However conflict is not the only antecedent. Problem redefinition often emerges from a need to clarify a problem which does not necessarily entail any negotiation of differing points of view. Rather, the latter circumstance leads to a refinement of the problem through collaborative sense-making again, wherein the children appear to regard each other as knowledge brokers and intelligence gatherers.

Exploring Children's Talk and Thinking

Although it does note movement and body language, most data are comprised of the children's talk. This begs the question, to what extent does talk provide a view of the children's social construction of knowledge? Anders Ericsson and Simon (1984) argue that verbal reports "can claim to being the closest reflection of the cognitive processes" (p.16). Primarily they posit that 'talk aloud' and 'think aloud' are examples of the direct verbalisations of thinking. However children and adults can be restricted by their command of language in making explicit their thinking. They may be more elaborate with drawing or writing about their thinking. Furthermore they may not see the need to make their thinking explicit. However, Mercer (1995) claims that talking about the process of learning is more common in peer discourse and that such exploratory talk aids the child's ownership of learning. The neo-Vygotskian perspective is that talk does not constitute some "kind of transparent window on the mind" (Mercer, 1994, p. 95) and is not 'think aloud' as proposed above. Instead, talk is a "social mode of thinking" (ibid) wherein information is shared, ideas exchanged and alternative viewpoints considered. Talk then does not necessarily constitute a direct reflection of one's thought but provides a channel in which to communicate with others and be influenced by others.

The dyad site and the conversation with the researcher provide a glimpse of how dyads can make sense of problems. This includes the ways in which they construct a shared view and jointly negotiate meaning. What do they do with their emerging ideas on the edge of their knowledge and how might the dyad site influence this? The following extract provides an example of how one dyad redefines a problem to clarify their understanding of it (L= Child 1; D= Researcher; M= Child 2; []= talking simultaneously)

L: [We've got] this side and this side but now we're getting stuck on this side so we need to move some numbers...
D: Which numbers seem to help to be moved? Which ones?
L: (No hesitation) The highest ones - 9, 8 and 7.
D: Why [are the]...
M: [Are you] sure?
D: Why do you think those highest ones are important?
L: Because we've only got it up to equal 14 (the last side).
M: Yeah with these ones here. And if you add those up together (the large numbers) you'll just have the little ones because the little ones are just like...(rolls her eyes upwards) well you have a hammer, you have the big stuff for the house, big hammer (pointing to big numbers) and stuff and then you have the little nails (pointing to the small numbers) to do the job for the um, house.

This metaphor of a house and the building of it with hammers (big numbers) and nails (little numbers) emerged as a way in which Megan made sense of the problem and helped them to overcome an impasse. Just prior to this Linda had suggested that they abandon the problem and return to it later. After Megan introduced the metaphor they both returned to it with enthusiasm. Their speech throughout their interaction took on the motifs of hammers and nails as a form of code for their communication e.g.:

L: Maybe we should try putting a hammer each on one side so it goes from highest to lowest on each side...
M: So [we've got 8]...
L: [And that leaves the little ones] which are the nails.
M: 9...8 for the side (putting the large numbers in the middle of each side). Well there would be 2 hammers on this...
L: 8, 9 um 7. I know why don't we put the 8 on a different side otherwise there would be 2. We'll put the 8 [here].
M: [Here] The 8, the 7 and the 9.
L: I'm just writing it in real light...
M: But we'll have to do kind of um...
L: Just write it in real small um...
M: So we'll try this one here (focusing on one side). The 8 and 6 are...(looks at Linda).
L: Um...14.
M: 14, And so 8, (whispering) we'll just write it really softly in here, what would be...8, 16...
L: A good one there would be to put a little nail.
M: A little nail but...
L: The littlest nail.

And at the end of that particular problem, Linda comments on the metaphor without prompting:

L: (Small voice) We're finished. The hammers and nails really helped.
D: How did the hammers and nails help?

M: Well, well you could say um, when you're building a really big house um you need lots of hammers to do it with...
L: You need hammels, you need hammers...
M: Yeah.
L: The big ones in the corners to keep the house standing...
M: Yeah and um, we were thinking of um... we needed LOTS of hammers but we didn't need that many...
L: Actually, we only needed three for the three corners because we need...like if we were making a triangle house, we need 3 big planks of wood for the corners and then...
M: Yeah so that would be, we could have...
(They talk over each other- indecipherable).
M: We could have 3 hammers and then you go, 1, 2, 3, 4, 5...(counting the circles between the corners)
L: 6.
M: 6 little nails and then you could go around.
D: I'm really interested in how you both understood what each other meant straight away about hammers and nails.
L: (Laughs).
D: And yet if I suddenly started talking to someone about "Oh yeah, those are hammers and those are nails." I think they may think I was a bit strange.
L: (Laughs).
M: (Laughs).
D: How, how was it you that you knew what each other was talking about straight away?
L: Because we've been with each other [a lot] (laughs)
M: [A long time].

That these girls knew each other well and were friends seemed to feature strongly in their perception of their mutual understanding and the way in which they socially constructed their knowledge. Being familiar with and comfortable with each other seems an important prerequisite for collaboration and the joint construction of knowledge when the problem is challenging. That this is always a necessary prerequisite is far from conclusive, though the construction of a common interpretation seems pivotal as evidenced also by Garton and Renshaw (1988). Of further interest was the way in which this dyad redefined the problem in order to make sense of it, to build a shared understanding based upon building materials rather than numbers. Smith (1995) states that:

> In the process of acquiring skills and information children transform them. When children are involved in social interaction they ignore some aspects of situations and participate in others and they change what they participate in to suit their uses. They forge new connections and reformulate existing ideas. (p. 9)

Megan and Linda had transformed the problem with their building metaphor which appeared to assist them with making the crucial connection between the size of the numbers and their placement in the triangle. In doing so their existing ideas were both challenged and reformulated. Smith (1995) argues that such collaborative dialogue "is a rich context for creativity" (p. 9).

Conclusion

This study lacks the immersion in classroom life and the recording of private talk that Alton-Lee and Nuthall (1992, 1993) have captured in their studies. The research questions

however required a somewhat more structured approach to investigate the affect of certain problem types and the children's influence on each other when investigating these problems. Limitations of collecting data with audio and video tape invariably runs the risk of making the children feel self-conscious and affect both the quantity and quality of talk that takes place, despite how subtly it is introduced. Similarly the mere presence of an adult may influence the type of talk children use with the likelihood of more task-related verbalisations occurring when an adult is present (Brody, Stoneman & Wheatley, 1984). Nevertheless, the actual problems appeared to encourage the children to converse readily with each other. The social context for the problem solving seems to encourage the children to make their thinking explicit which is evident thus far in this study and in others (Barnes & Todd, 1977; Garton & Renshaw, 1988; Mercer, 1995). The children's familiarity with the researcher, with each other and with conversations about their thinking and strategies has assisted with capturing a glimpse of the children's sense-making as it occurs and the ways in which they grapple with ideas on the edge of their understanding. Such a focus seems to be timely when considering the potential of peer dyads and the types of learning processes that may occur when dyads interact.

This study contributes to the educational research field through providing novel and fresh slants on collaborative peer dyads (from an interpretive paradigm), investigating what occurs when children collaborate on and redefine problems and giving rich detail on the effects of the problem type on both collaboration and problem redefinition. The essence of problem redefinition and collaborative sense-making is difficult to convey with quantitative methods. This study hopes to make a timely contribution to the collaborative peer dyad studies which have traditionally focused upon cognitive gain associated with introduced tasks (often Piagetian) in laboratory settings. While some studies have focused on different problems they have not ascertained a range of problem types and dyads' responses to these concomitant with their collaborative problem solving. The focus on problem redefinition, an aspect of creative thinking, highlights the conditions under which such thinking is likely to take place which has considerable pedagogical implications. The central phenomenon of collaborative sense-making emphasises the potential for children's dialogue as a source of knowledge construction.

As mentioned previously only one dyad had received any explicit instruction on how to work together collaboratively. It can be problematic therefore to assume beneficial influences of the problem types upon the children's ability or experience in collaboration or even to expect the children to work together. That they appear to do so with the open and fuzzy problems in most cases raises questions that cannot be clearly attributed to past experiences or instruction. It is a tribute to the children's tolerance and flexibility that they do participate with each other and the problems at hand as requested. This issue reminds me of how dependent such research is upon the goodwill and cooperation of the children involved. It is also a considerable imposition to ask children to work in pairs when they may not be comfortable in doing so. That no child resisted or appeared reluctant to work in a dyad is not a guarantee that they were enthusiastic or interested in doing so. To what extent was I threatening the children's sense of self and independence when asking them to work together? While the affective reactions to pair work of this nature constitutes another study beyond the scope of this one, it bears consideration when questioning the intent of the methodology.

Various issues and questions have arisen during this study and continue to require further examination. What is it about closed problems for example, that makes them so ambiguous for children? How do children collaboratively redefine problems? In what ways does the process of problem redefinition assist in problem clarification? How crucial is it that dyads are friends or at least self-chosen? How is persistence encouraged when working with a partner, especially a more confident peer? While the subcategories are

based upon speech acts intended for both social and individual meaning, what is obscured by combining these? These questions require further examination and comparison with propositions emerging from the data.

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Appendix 1

Subcategories

Accede:	To agree to or uncritically acquiesce with the effect of endorsing what has preceded. This is usually represented as a short statement implying agreement. e.g. Sam suggests that they have 6 bicycles and 3 tricylcles. Zane replies "Yeah". Sam says that after taking out 2 tricycles there's 12 wheels left. Zane replies "I know."
Correct or Counter (CC):	• To point out an inaccuracy or difference in interpretation e.g. Sam says: "I moved down here when I was two." Zane replies: "You mean UP here." e.g. Sam is looking for Napier on the map and Zane says: "You're looking in entirely the wrong place." • To propose a different idea/approach in direct contrast to one already given in discussion. e.g. Zane: "It'd probably be the same as Hamilton"; Sam: "No it's less, less population." e.g. Sam questions Zane's estimate of Hamilton's population which he thinks is too high "But look, this is actually bigger than this (comparing Wellington to Hamilton)."
Deduce	To use the information given to come to a conclusion. This is not necessarily at the end of a process or discussion but can occur during interaction also. The conclusion made is not necessarily final but is formed as a result of some prior information or realisation. e.g. Sam suggests that the population of Thames is about 10,000 according to the key they are using. Zane uses that population figure to confirm the number of vets there might be "So that means about 2." e.g. While watching Zane work out a problem Sam offers "You know it's going to be 35 again 'cause the letters are the same."
Dialogue Filler:	Comments that appear to offer nothing or little to the conversation other than to fill space and maintain discussion or momentum. e.g. "Well..." e.g. "Hmmm...that'd be..."
Direct:	To tell oneself or another what to do or give orders related to managing a way to proceed e.g. Zane tells Sam: "Go on to the South Island." e.g. Sam tells Zane to "Change that to 3, make it 3."
Hypothesise:	To suggest an explanation for a group of facts or offer a solution to a problem, accepted either as a basis for further

	verification or as likely to be true. Also, to speculate, suggest, surmise, theorise or moot. e.g. At the beginning of a problem Zane starts with: "They'd be 9 bicycles if it was just bicycles." e.g. "If there's 8 heads there's got to be 8 spiders" e.g. "So, we could do a 3 there or a 1"
Inform or Verify	• To make a statement that is intended to convey facts or knowledge this is sometimes a direct response to a question asking for information. e.g. Sam asks: "Is Abel Tasman a city?" and Zane replies: "That's a bay." • At other times it is the giving of unsolicited information. e.g. When discussing Wellington with Sam, Zane offers: "That's a major city." • And sometimes it emerges as if thinking aloud. e.g. "3 million and something. There's 3.2 million people in New Zealand." e.g. "I'll just do the circles first"
Non-verification:	To state that one is unsure or does not know rather than assert that something is incorrect or impossible e.g. Zane asks Sam if Napier is a city. Sam responds: "I don't know. I hardly know any cities in New Zealand."
Praise or encouragement:	To affirm an idea or action with a statement that conveys a positive judgement. e.g. "Good one!" e.g. "That's it - go on"
Seek verification or information:	To ask for confirmation of an idea or proposal or request an answer e.g. Zane asks "Christchurch is a bit bigger than Hamilton isn't it?" e.g. Sam asks "How many legs has a beetle?"
Self-correct:	To realise one's error and redress it by suggesting an alternative e.g. Sam says "And Wellington is the SAME as Hamilton!? (Then he realises they're using the wrong key for the map and gives Wellington more vets than Hamilton). So Wellington would be 6." e.g. Earlier in the discussion Zane suggested that Canterbury was a city. Later on when Sam suggests Canterbury Zane seems to realise the error and says "We'll do Dunedin. I don't think there is a Canterbury actually. Isn't it a district?"